Intercomparison of monthly Euro-Atlantic weather regimes obtained from different reanalysis and of their influence on wind energy resources

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1. Background and goals

- Synoptic climatology investigates atmospheric variability by classifying the complex dynamics of large-scale circulation in a few recurrent and persistent patterns, called "circulation regimes" or "weather regimes" (Michelangeli et al., 1995; Hannachi et al., 2017).
- The aim of this study is to compare the differences between the weather regimes as classified by three different modern reanalysis: JRA-55 (Kobayashi et al. 2015), ERA-Interim (Dee et al., 2011) and NCEP-NCAR (Kalnay et al., 1996).

2. Data and methodology

- Daily-means of **SLP and 10-m wind speed** fields were employed. Each of the three chosen dataset has a different spatial resolution: 1.25° (JRA-55), 0.75° (ERA-Interim) or 2.5° (NCEP). SLP data was preferred to geopotential height, even if it is noisier, because it doesn't show any temporal trend (Hafez and Almazroui, 2014).
- To classify the regimes, a **k-means cluster analysis with *N=4* clusters** was applied to the data of each month separately, as four is the preferred number of regimes in the Euro-Atlantic region [26.9°N-80.5°N, 85.6°W-45.6°E] (Yiou and Nogaj, 2004).
- Regime anomalies were measured by averaging the daily SLP anomalies belonging to each regime and month during 1981-2016. The **influence of each regime on 10-m wind speed** was measured by averaging daily 10-m wind speed anomalies belonging to each regime and month separately for JRA-55.
- To be able to compare the regime anomalies with the pattern correlation, JRA-55 and ERA-Interim were regridded to the same grid of NCEP (horiz.res. 2.5°) with a bilinear interpolation.

3.1. Results: regime anomalies and frequencies

- Figure 1 illustrates the spatial patterns of the monthly regime anomalies of the four regimes for **JRA-55 reanalysis**, ordered (from left to right) by **decreasing average frequency** of occurrence during 1981-2016. They often resemble the spatial patterns of the **NAO+**, **NAO-**, **blocking** or **Atlantic ridge** wintertime regimes (Salameh et al., 2008). Regime anomalies are globally stronger from October to March and weaker from April to September.
- Monthly frequencies vary from a maximum of 34.5% of Regime #1 in August to a minimum of 18.3% of regime #4 in the same month.

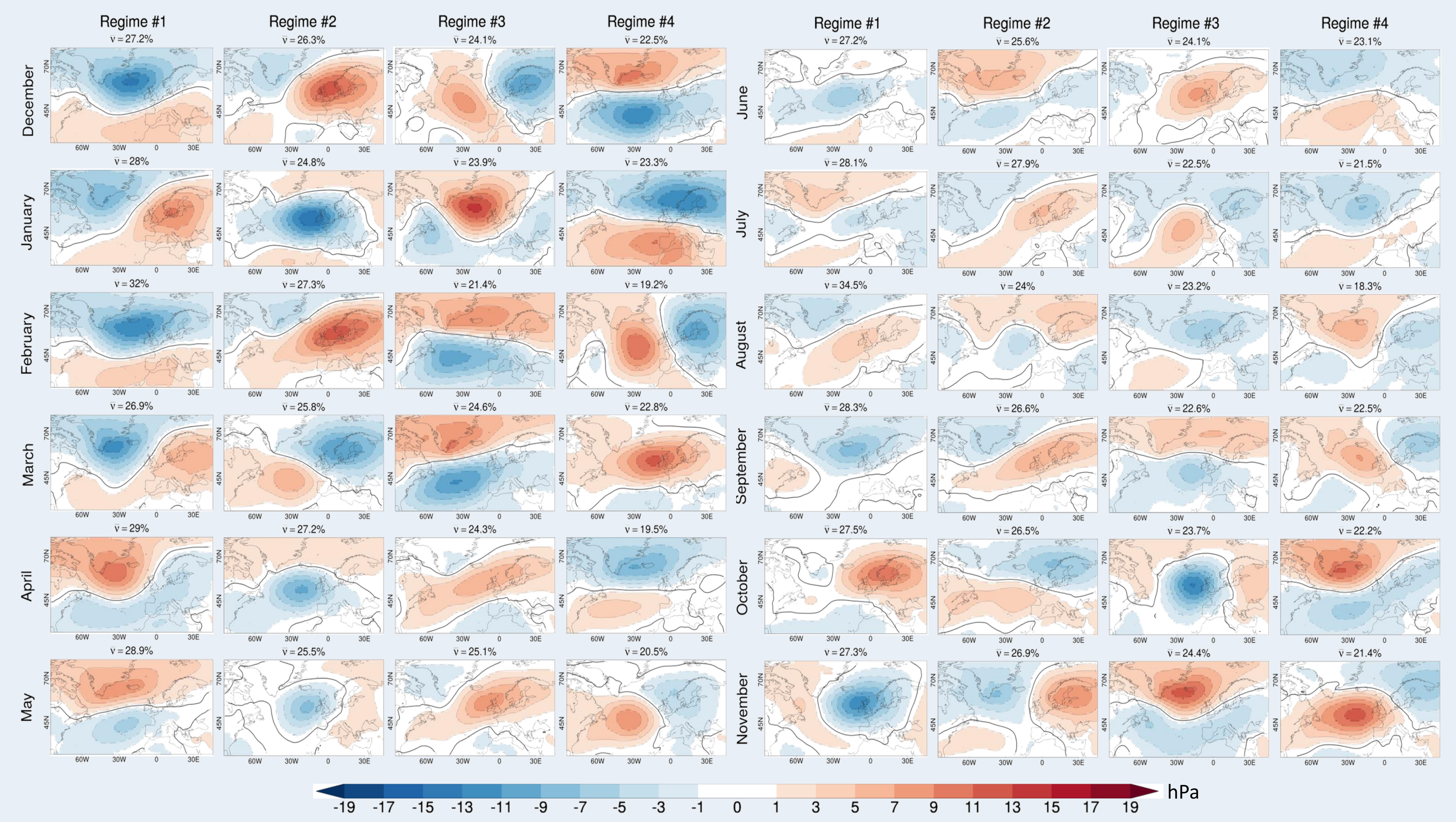

Figure 1. Spatial anomalies (hPa) of the four monthly regimes from December (top left row) to November (bottom right row) as classified for the **JRA-55** reanalysis. Regimes are shown, from left to right, in decreasing order of average monthly frequency (1981-2016). **Black lines** separate regions with positive and neg.anomalies.

- Comparison between JRA-55, ERA-Interim and NCEP revealed that they present almost identical spatial patterns, with **pattern correlations** between correspondent regimes of different reanalysis **always significant at 99% level of confidence, and higher than *r=0.95* in all months except August.**
- **In August, pattern correlations** between the regimes #4 of JRA-55 and ERA-Interim and between JRA-55 and NCEP **drop to *r=0.85*** for both pairs of regimes.
- The **average frequencies of occurrence** (1981-2016) of the regimes can vary slightly between the three reanalysis, but usually within ±1%. Differences higher than 1% are measured for regime #1 and #4 in **August** (JRA-55 av. frequency respectively higher or lower than ~4% compared to the other reanalysis) and for regime #2 and #4 in **December**, when NCEP freq. can be 2% lower than the other reanalysis (not shown).
- Lowest correlations between the **time series of the monthly frequencies** of pair of correspondent regimes from different reanalysis (i.e: the August time series in Figure 2) were detected during **July** ($r_{JRA55\text{-}NCEP} = 0.88$), **August** ($r_{JRA55\text{-}ERAInt} = 0.85$) and **December** ($r_{ERAInt\text{-}NCEP} = 0.92$). Correlations for all other months are always greater than *r=0.95*.

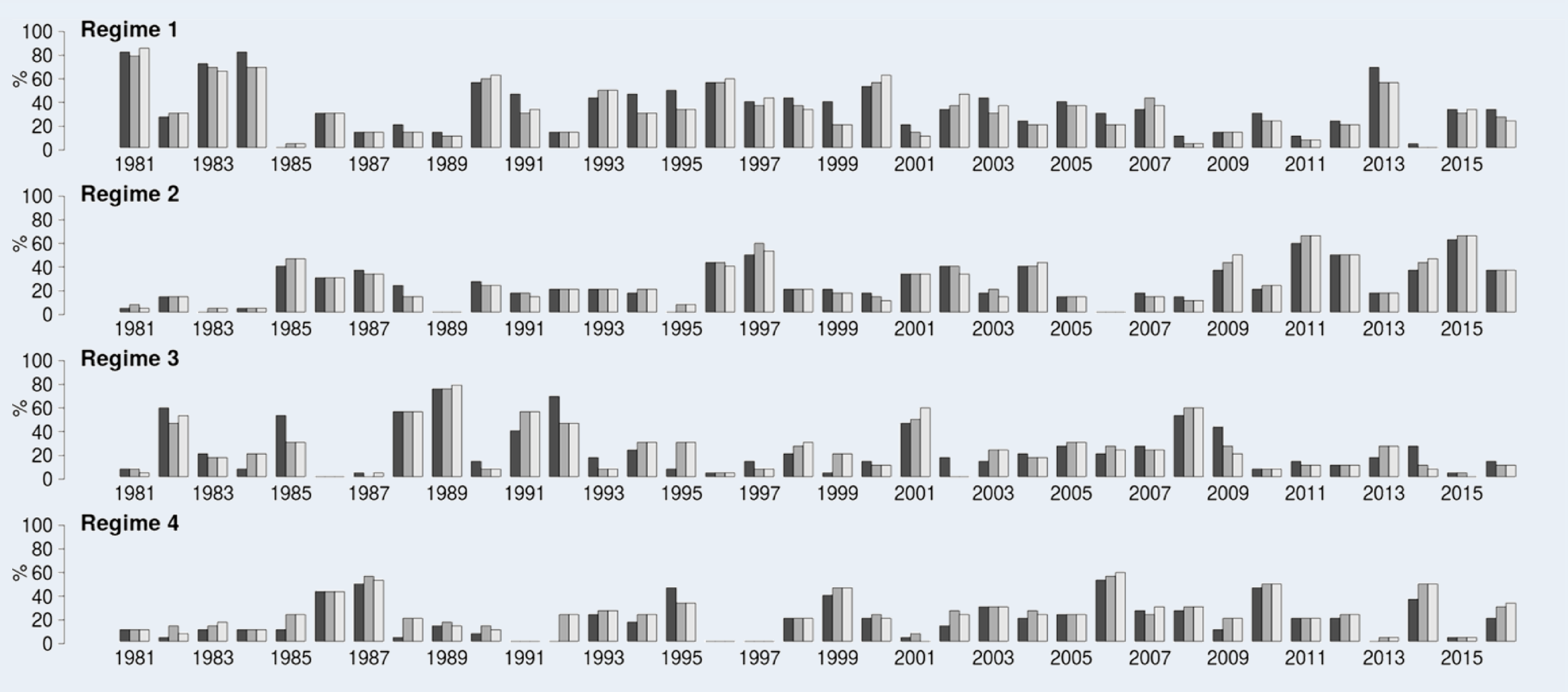

Figure 2. August monthly frequency time series from 1981 to 2016 of the four regimes (top to bottom) as measured by JRA-55 (black columns), by ERA-Interim (gray columns) and by NCEP (white columns).

3.2. Results: influence on wind speed

- Figure 3 shows the influence of each regime on monthly 10-m wind speed. For example, the red or blue influence areas shown for Regime #1 in December illustrates **where wind speed is higher or lower than average** during a **NAO+** episode (cfr. Figure 3 and Figure 1).
- Regimes have a **high influence in western and northern Europe and during winter months** and a low influence in the Mediterranean basin, eastern Europe and in summer months.

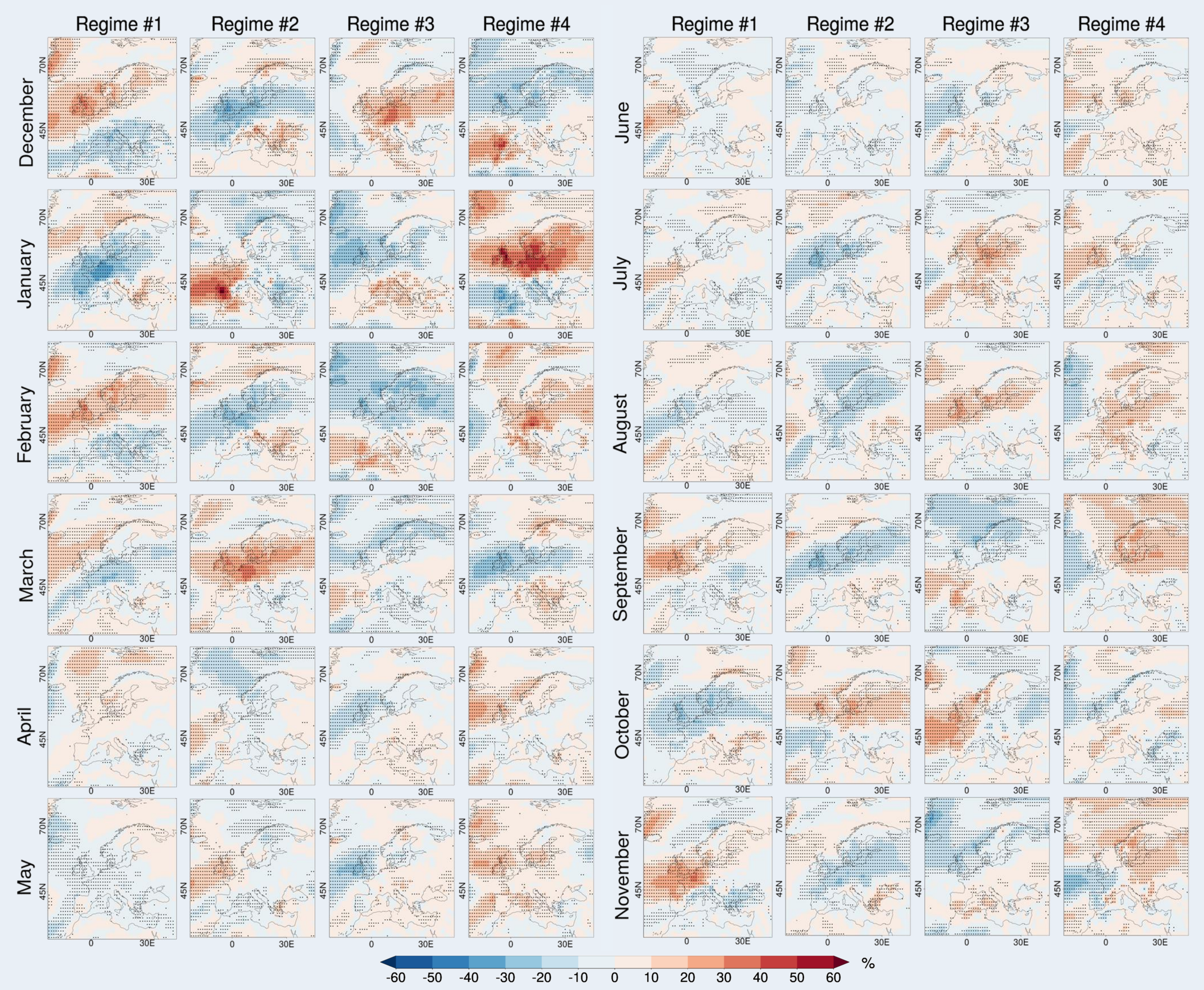

Figure 3. Average daily European 10-m wind speed anomalies belonging to each month (1981-2016) and regime for JRA-55 reanalysis, from December (top left row) to November (bottom right row). Wind anomalies (in m/s) were normalized for the mean climatological value at each point to obtain relative anomalies (in %). Black dots show areas with significant anomalies with a t-test at 95% confidence level.

- Each reanalysis reproduces the spatial patterns in Figure 3 in a slightly different way. To measure the disagreement, pattern correlations between 10-m wind speed spatial anomalies for a given regime and month were measured for each pair of correspondent regimes belonging to two different reanalyses (Table 1).

Table 1. Pattern correlations between 10-m wind speed anomalies for a given month and regime and two different reanalysis. Only correlations below *r=0.95* are shown. Yellow values represent correlations between 0.80-0.90 and red values are correlations lower than 0.80. Italic numbers represent not significant correlations at 95% confidence level.

	$r_{(JRA55\text{-}ERAI)}$				$r_{(JRA55\text{-}NCEP)}$				$r_{(ERAI\text{-}NCEP)}$			
Month	WR1	WR2	WR3	WR4	WR1	WR2	WR3	WR4	WR1	WR2	WR3	WR4
Jan					0.92	0.93	*0.87*	0.89	*0.93*	0.90	0.90	0.94
Feb					0.88	*0.85*	0.91	0.90	0.88	0.91	0.92	0.90
Mar					0.85	*0.89*	0.89	*0.92*	0.93	*0.88*	0.90	*0.90*
Apr					0.86	0.90	0.90	0.83	0.86	0.91	0.87	0.92
May					0.84	0.89	0.85	0.89	0.88	0.90	0.90	
Jun			0.94	0.93	0.86	*0.88*	*0.87*	0.82	0.91	*0.82*	*0.87*	0.88
Jul				0.88	0.88	0.79	0.86	0.75	0.76	0.91	0.82	0.84
Aug	0.90	0.94	0.82	0.91	0.82	*0.87*	0.77	0.83	0.89	0.91	0.88	0.88
Sep					0.91	0.84	0.88	0.89	0.87		0.85	0.91
Oct	0.86				0.85	0.94	0.90	0.88	0.91		0.86	0.90
Nov					0.91	0.84	0.88	0.89	*0.86*	0.91	0.89	0.91
Dec					0.91	0.89	0.89	0.86	0.91	0.92	0.90	0.87

- Overall, **pattern correlations are lower than in section 3.1**, mainly because two variables are employed to measure wind anomalies for each regime: SLP (to classify regimes) and 10-m wind speed.
- **Lowest correlations were measured in July** (*r=0.75*) followed by August (*r=0.77*) and more generally for the whole JRA55-NCEP pair (central columns in Table 1).
- Correlations between JRA-55 and ERA-Interim are sistematically higher than between JRA-55 and NCEP, or ERA-Interim and NCEP (four left columns in Table 1). Thus, **wind speed regime anomalies measured by NCEP are the more different ones of the three reanalysis.**

4. Conclusions

- **Very small differences** were measured when comparing both spatial patterns and the frequencies of the regimes classified by the three chosen reanalysis, as **correlations were generally greater than *r=0.95***. This indicates that SLP is a consistent variable among the reanalyses.
- **Higher differences** were detected when comparing wind speed regime anomalies, particularly the ones proceeding from NCEP, for which **pattern correlation decreases to *r=0.75* in July**.

5. References

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The research leading to these results has received funding by the New European Wind Atlas (NEWA) project, which is part of the European Commission's 7th Framework Programme (FP7-ENERGY)

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